# RAMI-V: Results

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RAMI Workshop 2023

European Commission

# RAMI-V canopies

## ACTUAL

Järvselja Pine Stand (Summer) (HET07_JPS_SUM)

Järvselja Birch Stand (Summer) (HET09_JBS_SUM)

Ofenpass Pine Stand (Winter) (HET08_OPS_WIN)

Järvselja Birch Stand (Winter) (HET15_JBS_WIN)

Wellington Citrus Orchard (HET14_WCO_UND)

Agricultural crops: Short Rotation Forest (HET16_SRF_UND)

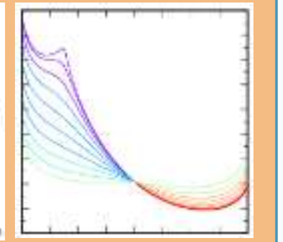
Savanna pre-fire (HET50_SAV_PRE)

Wytham Wood (HET51_WWO_TLS)

## ABSTRACT

**Homogeneous**

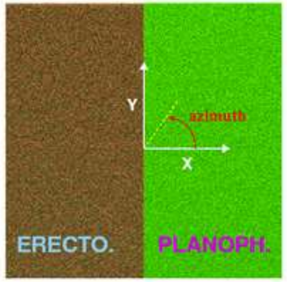
Anisotropic Background (HOM23,24,25/HOM33,34,35)

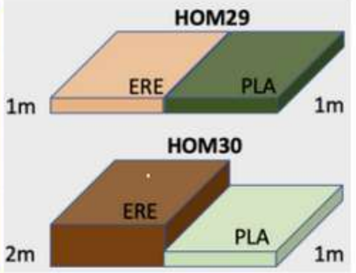


Lambertian

Two-layer canopy (HOM26,27,28/HOM36,37,38)

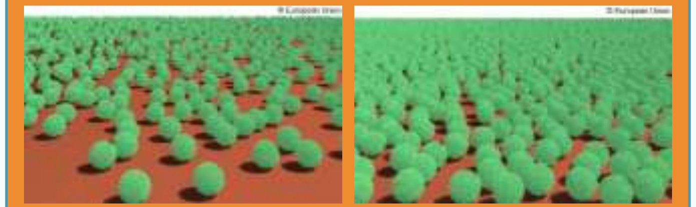
Adjacent canopies (HOM29,HOM30)



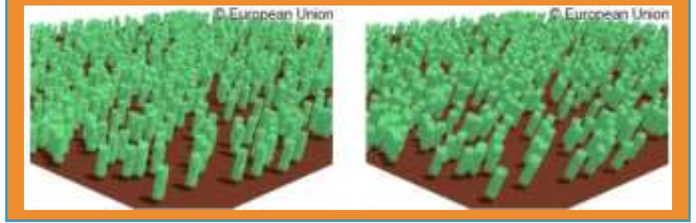

**Heterogeneous**

Anisotropic background (HET10,11,12/HET20,21,22)



Two-layer canopy (HET16,17,18/HET26,27,28)

Constant Slope (HET23,24/HET33,34)



# New RAMI-V Actual Scenes


Savanna pre-fire (HET50_SAV_PRE), South Africa

Wytham Wood (HET51_WWO_TLS), UK

- **Semi-empirical** scene based on actual sampling campaign (Disney et al., 2011)
  - Predefined model trees
  - Sparse vegetation (3 tree types, d=599/ha)
  - Grass covered surface (200k plants/ha)

- **Empirical** scene based on the TLS sampling after Calders et al. (2018)
  - Reshaped to flat surface (all trees to z=0) to guarantee energy conservation
  - Cropped to 1-ha, 7 tree types, LAI overest. (buggy scene)
  - Surface: area averaged spectral properties

| RAMI-V id | Name | Plants Density $[ha^{-1}]$ | Scene LAI $[m^2/m^2]$ | Fractional cover [%] | Maximal height [m] | Primitives in the scene |
|---|---|---|---|---|---|---|
| HET50 | UCL Savanna | 599 (trees) | 0.09 | – | 11.31 | 4,718,130 (tri) |
| | | $2 \times 10^5$ (grass) | 0.0026 | – | – | 1,400,000 (cyl) |
| HET51 | UCL Wytham Wood | 528 (crowns files) | 7.59 | – | around 30 m | 6,124,335 (tri) |
| | | 558 (stems files) | – | – | – | 1,715,905 (ccyl) |

*Disney, M. I. et al., (2011 ), Remote Sensing of Environment,115 (8): 1866-1881*
*Calders, K., et al (2018), Remote Sensing,10(6):1-15.*

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# Spectral Configuration

*fabs* ftran**

- **13 spectral bands** were selected from 440 nm to 2200 nm
- Combination of OLCI, MSI and MODIS bands
- **brf*, bhr, dhr** computed for all bands, **fabs** and **ftran** only in the bands pertaining to **PAR**
- All spectral scatterings properties were provided

$$X = \frac{\int_0^\infty S_{0\lambda} R_\lambda x_\lambda d\lambda}{\int_0^\infty S_{0\lambda} R_\lambda d\lambda}; \; X = Tran, Refl$$

| | OLCI | $\lambda_c$ (nm) | MSI | $\lambda_c$ (nm) | MODIS | $\Delta\lambda$ (nm) | RAMI-V |
|---|---|---|---|---|---|---|---|
| 1 | O03 | 442.5 | M01 | 443 | MD3 | 459-479 | O03 |
| 2 | O04 | 490 | M02 | 490 | | | O04 |
| 3 | O06 | 560 | M03 | 560 | MD4 | 545-565 | O06 |
| 4 | O08 | 665 | M04 | 665 | MD1 | 620-670 | O08 |
| 5 | O10 | 681.25 | | | | | O10 |
| 6 | O11 | 708.75 | M05 | 705 | | | O11 |
| 7 | O12 | 753.75 | M06 | 740 | | | O12 |
| 8 | | | M08 | 842 | | | M08 |
| 9 | O17 | 865 | M8a | 865 | MD2 | 840-876 | O17 |
| 10 | | | | | MD5 | 1230-1250 | MD5 |
| 11 | | | M11 | 1610 | MD6 | 1630-1650 | M11 |
| 12 | | | | | MD7 | 2105-2155 | MD7* |
| 13 | | | M12 | 2202 | | | M12* |

# Angular Configuration

- RAMI-V was designed to be oriented to real satellite observation geometries
- For **abstract** scenes the observation angles were computed for seven different latitudes (**30°S to 60°N in steps of 15°**; **LON=22.5°**) for **Jan, Apr, and Jul** for OLCI, MSI and MODIS channels
- Meas: **brf_sat** uses all these configurations, while **brf*, dhr,** and **fabs ftran** uses their period averaged summaries

## ABSTRACT scenes

| Scene | Latitude | Geometry (S3 OLCI) | Geometry (Terra MODIS) | Geometry (S2 MSI) |
|---|---|---|---|---|
| All Abstract | -30.0 | olci_30S.txt (51) | modis_30S.txt (364) | msi_30S.txt (9) |
| All Abstract | -15.0 | olci_15S.txt (44) | modis_15S.txt (322) | msi_15S.txt (9) |
| All Abstract | 0.0 | olci_00N.txt (41) | modis_00N.txt (81) | msi_00N.txt (9) |
| All Abstract | 15.0 | olci_15N.txt (45) | modis_15N.txt (323) | msi_15N.txt (9) |
| All Abstract | 30.0 | olci_30N.txt (52) | modis_30N.txt (364) | msi_30N.txt (9) |
| All Abstract | 45.0 | olci_45N.txt (65) | modis_45N.txt (364) | msi_45N.txt (19) |
| All Abstract | 60.0 | olci_60N.txt (66) | modis_60N.txt (364) | msi_60N.txt (16) |

Table 2: input geometries to be used for all abstract canopies

# Angular Configuration

- **Actual scenes were instead associated to fixed coordinates accordingly to the biome type.**

| Scene | Site | State | Coord Lat, Lon [°] | Jan-Feb [°] | Apr-May [°] | Jul [°] | $d_{S3}$ | $d_{MOD}$ | $d_{S2}$ |
|---|---|---|---|---|---|---|---|---|---|
| HET07, HET09 | Järvselja | Estonia | 58.3N, 27.3E | - | 56 153 | 41 147 | 75 | 97 | 9 |
| HET08, HET15 | (winter) | | | 76 155 | 56 153 | - | | | |
| HET14 | Wellington | South Africa | 33.6S, 18.9E | 42 076 | 60 045 | 67 041 | 46 | 57 | 18 |
| HET16 | Zerbolo | Italy | 45.3N, 8.9E | 71 153 | 36 137 | 34 130 | 54 | 68 | 12 |
| HET50 | Skukuza | South Africa | 25.0S, 31.5E | 37 089 | 50 051 | 60 041 | 42 | 55 | 14 |
| HET51 | Wytham | UK | 51.7N, 1.3W | 75 154 | 46 147 | 35 138 | 63 | 80 | 8 |

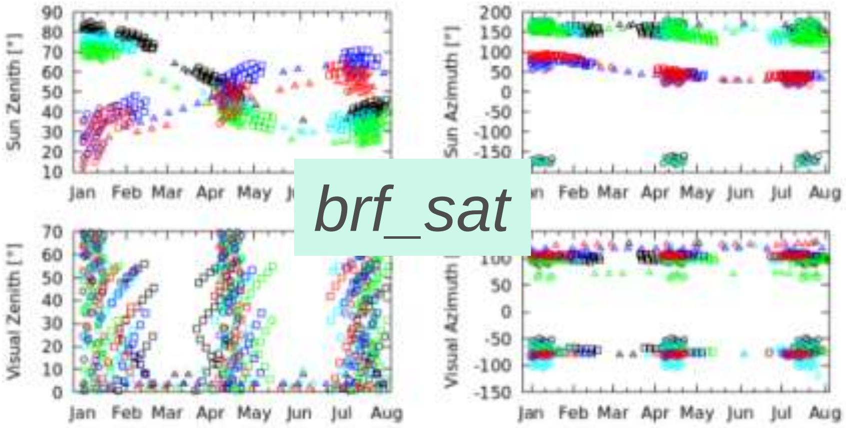
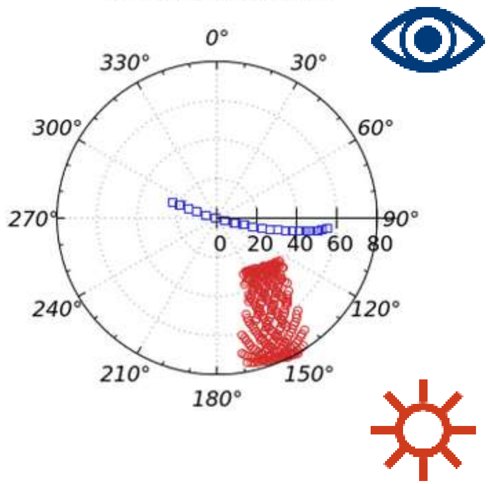



Figure 2: Time series of the Solar and Viewing angles for MODIS (circles), OLCI (squares) and MSI (triangles) over Järvseljia (black), Wytham Wood (cyan), Zerbolo (green), the northern hemisphere sites, Skukuza (red) and Wellington (blue), the southern sites. The

OLCI angle definition




## ACTUAL scenes

| Scene *Site* | Geometry (OLCI) | Num of cases | Geometry (MODIS) | Num of cases | Geometry (MSI) | Num of cases |
|---|---|---|---|---|---|---|
| HET07_JPS_SUM *Järvselja* | olci_jar.txt | 75 | modis_jar.txt | 97 | msi_jar.txt | 9 |
| HET08_OPS_WIN *Järvselja* | olci_jar.txt | 75 | modis_jar.txt | 97 | msi_jar.txt | 9 |
| HET09_JBS_SUM *Järvselja* | olci_jar.txt | 75 | modis_jar.txt | 97 | msi_jar.txt | 9 |
| HET15_JBS_WIN *Järvselja* | olci_jar.txt | 75 | modis_jar.txt | 97 | msi_jar.txt | 9 |
| HET14_WCO_UND *Wellington* | olci_wel.txt | 46 | modis_wel.txt | 57 | msi_wel.txt | 18 |
| HET16_SRF_UND *Zerbolo* | olci_zer.txt | 54 | modis_zer.txt | 68 | msi_zer.txt | 12 |
| HET50_SAV_PRE *Skukuza* | olci_sku.txt | 42 | modis_sku.txt | 55 | msi_sku.txt | 14 |
| HET51_WWO_TLS *Wytham Wood* | olci_wwo.txt | 63 | modis_wwo.txt | 80 | msi_wwo.txt | 8 |

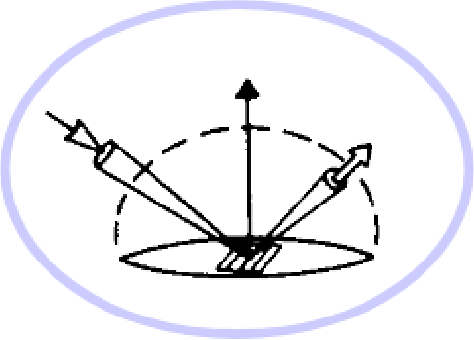
# RAMI-V Measurements

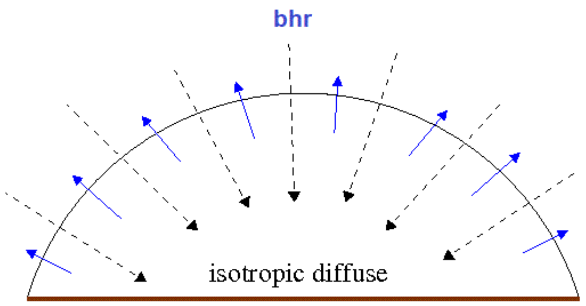
- BRFs: Principal and Orthogonal plane, Azimuthal ring (37°), Actual satellite geometries (MSI, OLCI, MODIS)
  - *single and multiple scattering also resolved individually for PP and OP*

- Albedo (directional-hemispherical and bi-hemispherical reflectance)

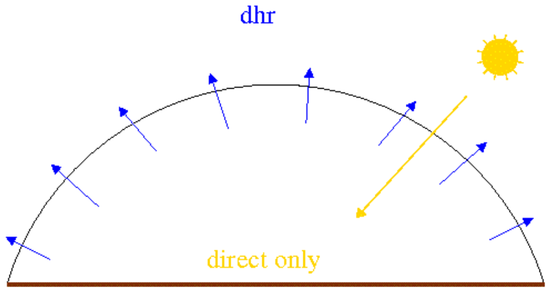
- Absorption (total and foliage), transmission through the canopy and transects.

- Digital Hemispherical Photography (DHP)







# RAMI experiments

- **<Experiment> = <scenario> + <measurement>**
  - <Scenario> = <scene> + <spectral> + <geometry>
  - **30+8** scenes, **13** bands, **21** geoms (abstract) / **2,3** (actual), **20** measurements
- **~106.5 K** experiments in RAMI-V (**3.5 K** Actual)
- **14** participants
- **~600 K** .mes files

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# Measurements performed by Models

| Model Name | BRFs brfpp | brfop | uc | co | mlt | brfazim | brfsat | Fluxes bhr | dhr | Absorption fabs | Transmission ftran |
|---|---|---|---|---|---|---|---|---|---|---|---|
| dart | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| dirsig5 | ✓ | ✓ | - | ✓ | - | ✓ | - | ✓ | ✓ | - | - |
| discret | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ |
| eradiate | ✓ | ✓ | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | - | - |
| flies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| frt13 | - | - | - | - | - | - | - | - | - | - | - |
| less | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - |
| librat | - | - | - | - | - | - | - | - | - | - | - |
| rapid | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | - | - | - |
| raytran | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| renderjay | - | - | - | - | - | - | - | - | - | ✓ | ✓ |
| spartacus | - | - | - | - | - | - | - | - | - | - | - |
| starter1 | ✓ | ✓ | - | - | - | - | ✓ | - | - | - | - |
| wps | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | ✓ | ✓ | ✓ |

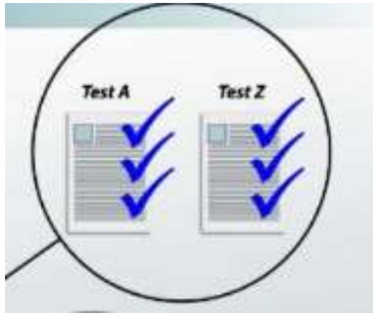
**ABSTRACT scenes**

| Model name | BRF (tot and filtered) pp | op | uc | co | mlt | BRF (tot only) azim | sat | Fluxes bhr | dhr | fabs | ftran | Fisheye thp | $P_{tot}$ % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| dart | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 100.0 |
| raytran | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 99.4 |
| wps | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | - | - | 🍃 | 🍃 | 🍃 | - | 86.2 |
| less | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | - | 🍃 | 83.9 |
| dirsig5 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | 🍃 | - | 🍃 | 🍃 | - | - | - | 75.2 |
| flies | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | ✓ | ✓ | - | 60.8 |
| rapid | ✓ | ✓ | ✓ | ✓ | ✓ | - | ✓ | - | - | - | - | - | 32.0 |
| spartacus | - | - | - | - | - | - | - | ✓ | ✓ | ✓ | ✓ | - | 18.6 |
| frt13 | ✓ | ✓ | ✓ | ✓ | ✓ | - | - | - | - | - | - | - | 14.5 |
| librat | ✓ | ✓ | - | - | ✓ | - | - | - | - | - | - | - | 8.7 |
| eradiate | ✓ | ✓ | ✓ | ✓ | - | ✓ | - | ✓ | ✓ | - | - | - | 2.8 |
| renderjay | - | - | - | - | - | - | - | - | - | ✓ | ✓ | - | 0.9 |

**ACTUAL scenes**

* Complement to the table $P_{tot}$
*discret: 16%; starter1: 0.5%*

# Internal Consistencies




- Energy conservation (λ) $\Delta F = 1 - T(1-\alpha) - A - R$
- BR… $- \rho_{mlt})$
- BR…
  - T… e
    c… by
    g…
- Alb…

| Test | Name | Required Measurements | M | Bands | r4 |
|---|---|---|---|---|---|
| r5cc1 | Energy conservation | dhr (bhr), ftran, fabs | 5 | PAR | y+ |
| r5cc2 | BRF consistency | brfpp(op), co, uc, mlt | 9 | All | y |
| $r5cc2_1$ | BRF vs Albedo | brfpp(op), dhr (bhr) | 9(10?) | All | n |
| $r5cc2_2$ | Albedo vs $(F^{\uparrow}/F^{\downarrow})_{TOC}$ | dhr (bhr), ftran_tot_vprof | 4 | PAR | n |
| r5cc3 | Spectral consistency | brfpp(op)_uc_sgl | X | All | r |

Table 6: List of the consistency checks applied in RAMI-V phase. M is the number of models for which the test was applied. The last column specifies if a test was inherited from RAMI-IV phase: (y/n/r) stand for (yes/no/revised). The + symbol indicates that an extended test with respect to RAMI-IV phase has been implemented.

- Spectral consistency (un-collided BRF vs Input surface properties).

$$|\Delta_S(m,\Omega_v)| = \frac{1}{N_S(m)} \sum_{\zeta=1}^{N_\zeta^m} \sum_{i=1}^{N_{\Omega_i}^m} \left| \frac{\rho_{bgd}(\lambda_1,\zeta,\Omega_v,i)}{\rho_{bgd}(\lambda_2,\zeta,\Omega_v,i)} - \frac{\rho_{uc}^m(\lambda_1,\zeta,\Omega_v,i)}{\rho_{uc}^m(\lambda_2,\zeta,\Omega_v,i)} \right|$$

- Results in %, *flies* analysis to be updated for both energy and BRF Consistency. The r5cc2 test produces results in line with other models on the last revision.

# Internal Consistencies

| Test | Name | Required Measurements | M | Bands | r4 |
|---|---|---|---|---|---|
| r5cc1 | Energy conservation | dhr (bhr), ftran, fabs | 5 | PAR | y+ |
| r5cc2 | BRF consistency | brfpp(op), co, uc, mlt | 9 | All | y |
| $r5cc2_1$ | BRF vs Albedo | brfpp(op), dhr (bhr) | 9(10?) | All | n |
| $r5cc2_2$ | Albedo vs $(F^{\uparrow}/F^{\downarrow})_{TOC}$ | dhr (bhr), ftran_tot_vprof | 4 | PAR | n |
| r5cc3 | Spectral consistency | brfpp(op)_uc_sgl | X | All | r |

$$\Delta F_m = \frac{1}{N_F(m)} \sum_{\lambda=1}^{N_\lambda^m} \sum_{\zeta=1}^{N_\zeta^m} \sum_{i=1}^{N_{\Omega_i}^m} \Delta F_m(\lambda, \zeta, i)$$

| RT Model | $\Delta F_m$ | $\Delta F_{50}$ | $\lvert\Delta F_{max}\rvert$ | $\sigma_{\Delta F}$ | $f_N$ |
|---|---|---|---|---|---|
| dart | 0.15 | 1.1E-4 | (-) 4.6 | 0.6 | 3440 |
| flies | -16.6 | -15.7 | (-) 96.4 | 17.2 | 3340 |
| raytran | 0.50 | 4.0E-2 | (+) 48.3 | 3.1 | 3440 |
| wps | 0.17 | 0.18 | (-) 4.40 | 0.68 | 3250 |
| spartacus(*) | 7.4E-5 | 4.7E-5 | (+) 6.9E-4 | 1.5E-4 | 80 |

| RT model | Heterogeneous | | | Homogeneous | | | Actual | Scale |
|---|---|---|---|---|---|---|---|---|
| | Ani | Two | Con | Ani | Two | Adj | | Factor |
| dart | 6.4 | 4.7 | 5.0 | -3.7 | -11 | 0.24 | 2.5 | $10^{-10}$ |
| dirsig5 | - | - | - | - | - | - | -2.6 | $10^{-2}$ |
| discret | - | - | - | 1.0 | - | - | - | $10^{-9}$ |
| flies | 12.6 | 2.7 | 5.4 | 6.4 | 0.3 | 1.6 | 7.9 | $10^{-2}$ |
| frt13 | - | - | - | - | - | - | 2.9 | $10^{-9}$ |
| less | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - |
| rapid | - | - | - | - | 28 | 8.7 | 4.5 | $10^{-10}$ |
| raytran | -18 | 19 | -21 | -3.1 | -120 | 18 | -7.0 | $10^{-9}$ |
| wps | 39 | 20 | 22 | 5.8 | 5.3 | 4.9 | 3.0 | $10^{-6}$ |

Table 8: BRF consistency. Average of the absolute difference between the sum and the total BRF, subdivided by scene category. The last column contains the scale factor of the values given in the previous columns.

| RT Model | $T_2$ |
|---|---|
| dart | $-0.03 \pm 0.31$ |
| flies | $1.0 \cdot 10^{-4} \pm 0.024^1$ |
| raytran | $-4.3 \cdot 10^{-5} \pm 0.003$ |
| spartacus | $-0.04 \pm 0.04$ |

Table 10: Average and standard deviation of the difference between `ftran_tot_vprof` and the corresponding **bhr** (or **dhr**). (1) The values obtained for *Flies* were filtered to consider only differences below 10% (being them 2400, and the remaining measurements were flagged as suspicious).

- Results in %, *flies* analysis to be updated for both energy and BRF Consistency. The r5cc2 test produces results in line with other models on the last revision.

# Internal Consistencies: r5cc2_1

| Test | Name | Required Measurements | M | Bands | r4 |
|---|---|---|---|---|---|
| r5cc1 | Energy conservation | dhr (bhr), ftran, fabs | 5 | PAR | y+ |
| r5cc2 | BRF consistency | brfpp(op), co, uc, mlt | 9 | All | y |
| $r5cc2_1$ | BRF vs Albedo | brfpp(op), dhr (bhr) | 9(10?) | All | n |
| $r5cc2_2$ | Albedo vs $(F^{\uparrow}/F^{\downarrow})$ [illegible] | dhr (bhr), ftran_tot_vprof | 4 | PAR | n |
| r5cc3 | Spectral consistency | brfpp(op)_uc_sgl | X | All | r |

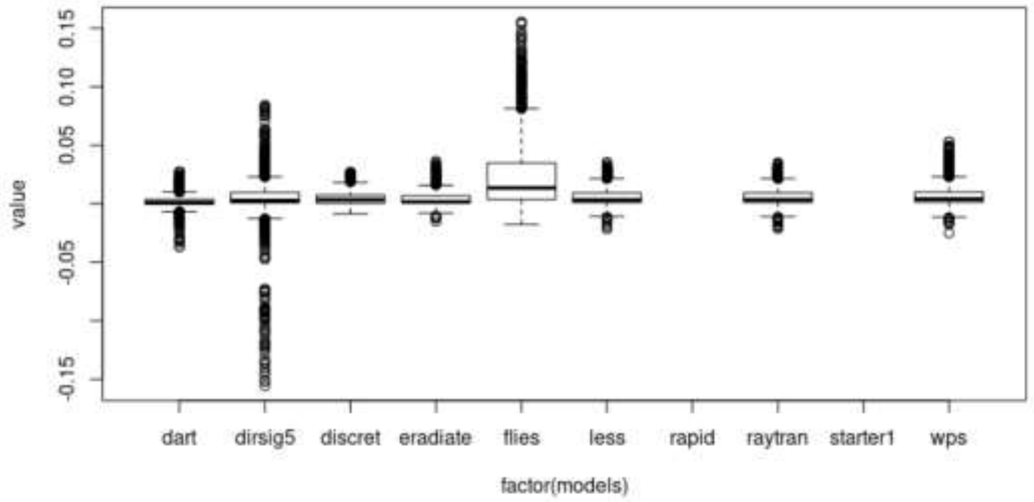
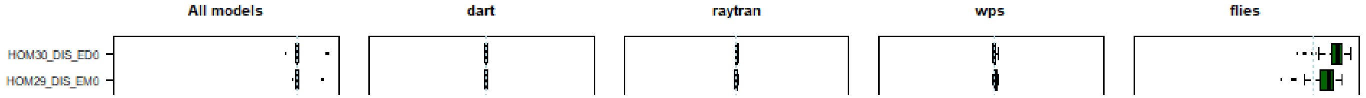


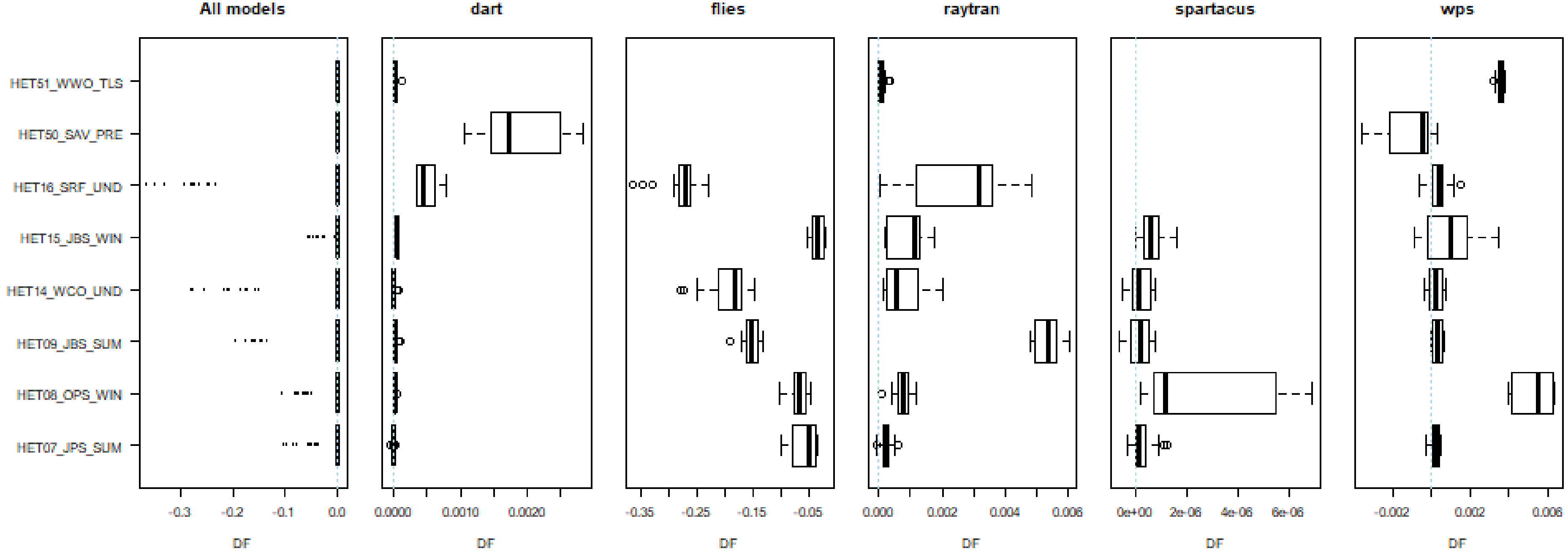

Figure 8: Distribution of the bias of DHR as obtained by integration of the BRDF function obtained from the .... and the DHR as provided by the models over all latitudes (geometries) and bands.

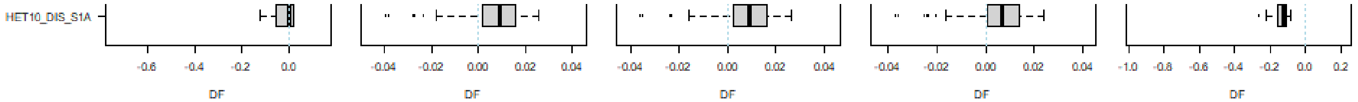
- Results in %, *flies* analysis to be updated for both energy and BRF Consistency. The r5cc2 test produces results in line with other models on the last revision.

# Internal Consistencies: r5cc1 (additional slide)

| Test | Name | Required Measurements | M | Bands | r4 |
|---|---|---|---|---|---|
| r5cc1 | Energy conservation | dhr (bhr), ftran, fabs | 5 | PAR | y+ |
| r5cc2 | BRF consistency | brfpp(op), co, uc, mlt | 9 | All | y |
| $r5cc2_1$ | BRF vs Albedo | brfpp(op), dhr (bhr) | 9(10?) | All | n |
| $r5cc2_2$ | Albedo vs $(F^{\uparrow}/F^{\downarrow})_{TOC}$ | dhr (bhr), ftran_tot_vprof | 4 | PAR | n |
| r5cc3 | Spectral consistency | brfpp(op)_uc_sgl | X | All | r |

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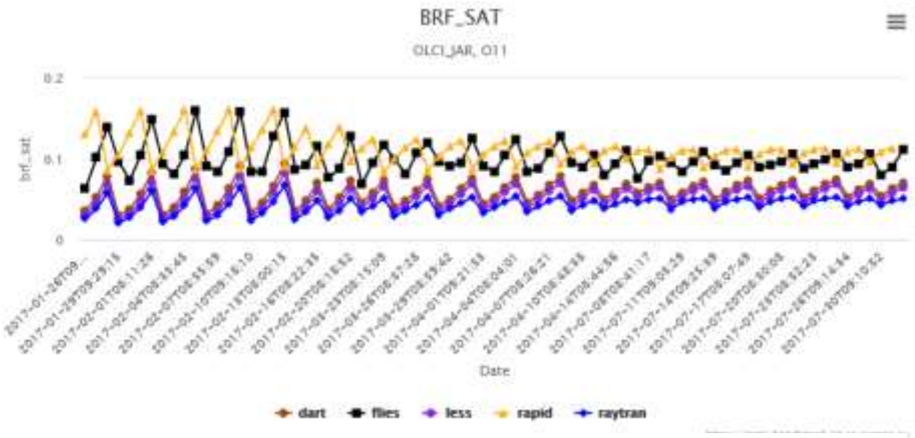
# Preliminary results

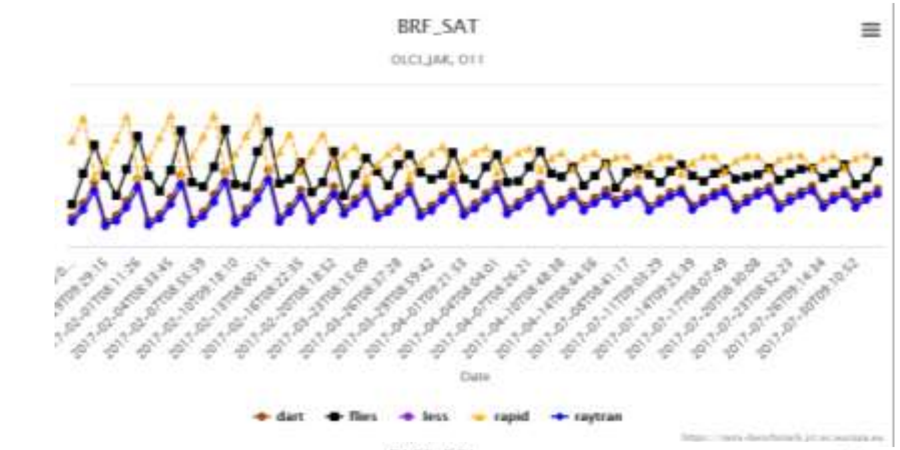
Järvselja Pine Stand (Summer)
**HET07_JPS_SUM**

**brf_sat**

2021

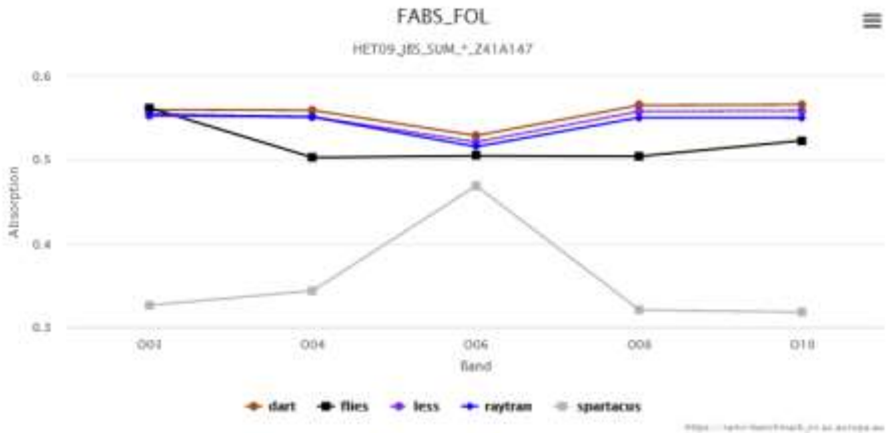


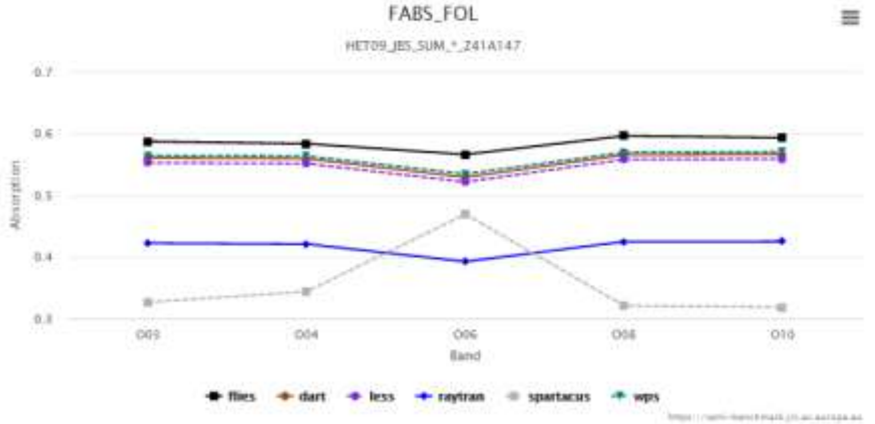

2023




Järvselja Birch Stand (Summer)
**HET09_JBS_SUM**

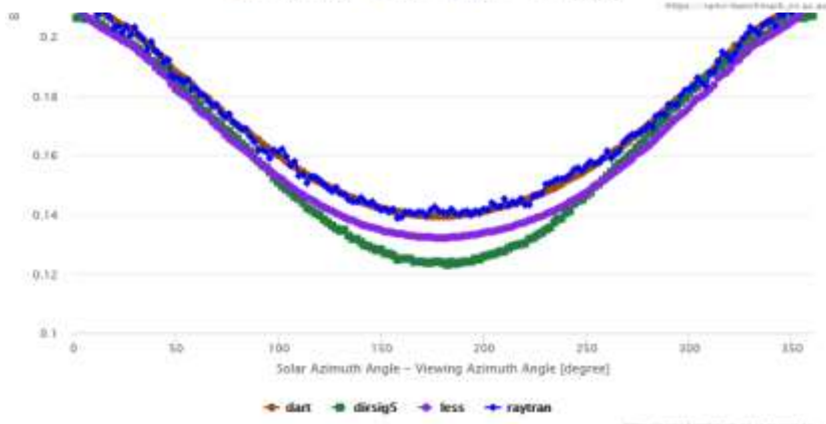
**fabs_fol**

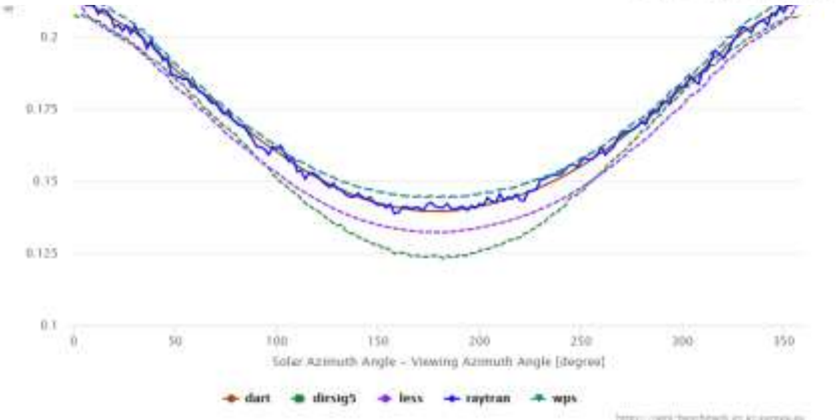



Savanna pre-fire
**HET50_SAV_PRE**

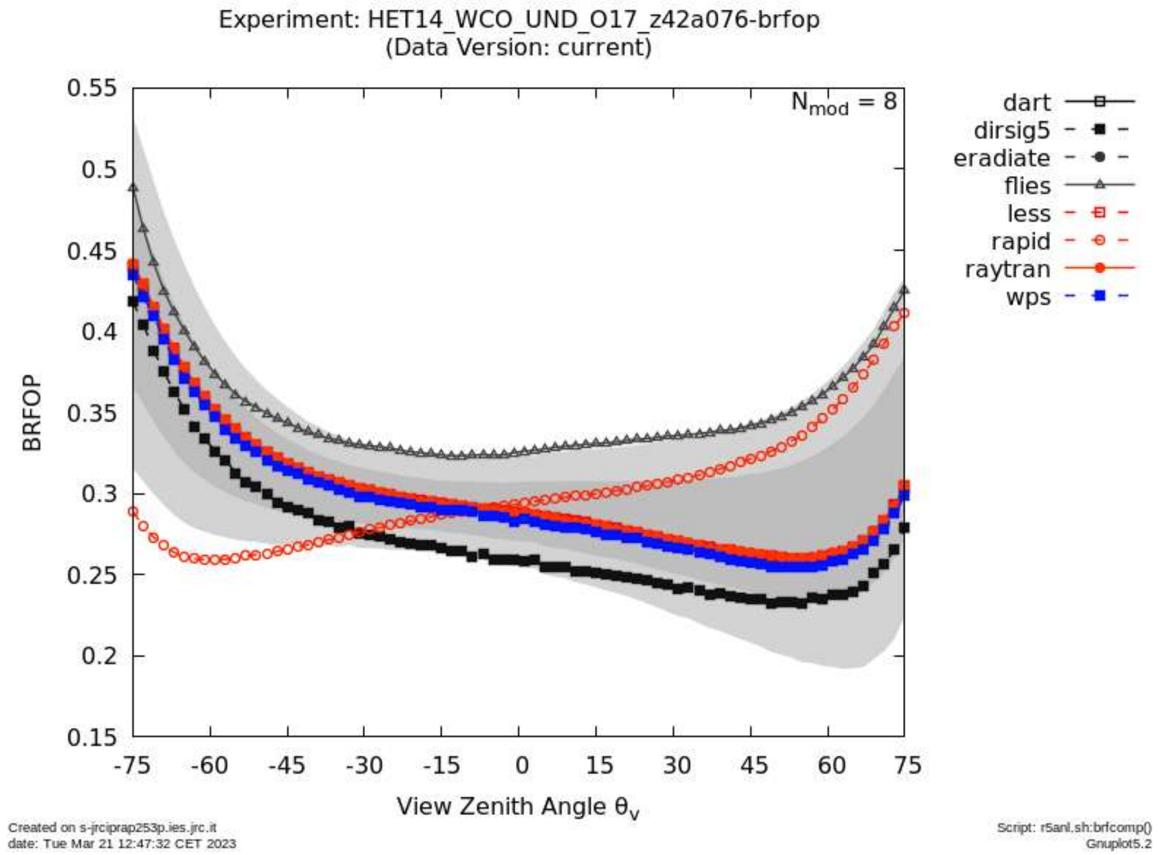
**brfazim**



# Feedback Phase from 12/2021 to 05/2023

- A **feedback phase** on preliminary results was established to highlight major issues/inconsistencies due to wrong input rather than model uncertainty.
- In a 100k+ experiments scenario, with 14 participant models, it was necessary to adopt criteria to identify the inconsistency as much automatically as possible.
- We adopted a simple ***Chauvenet*** criteria being the participation to common experiment ranging between 3-8 models.

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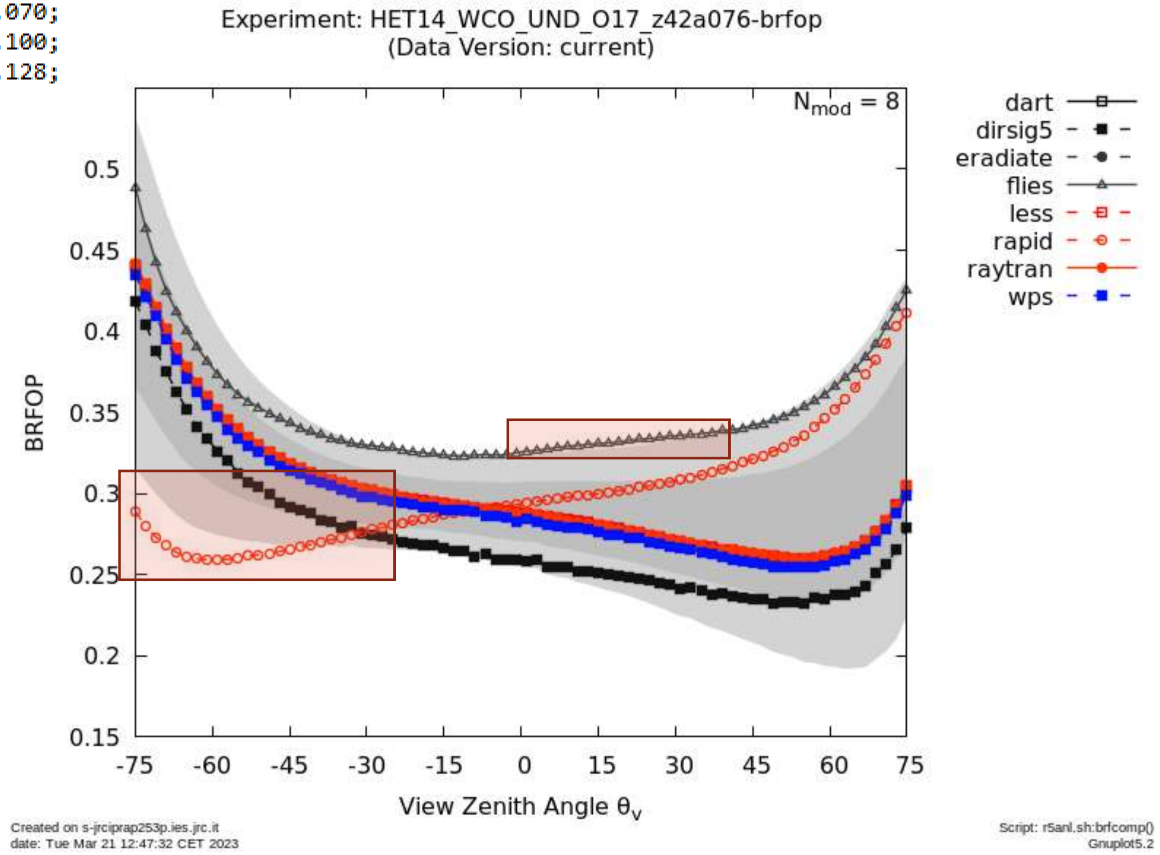
# Feedback Results

| Chauvenets table | |
|---|---|
| 3 | 1.383; |
| 4 | 1.534; |
| 5 | 1.645; |
| 6 | 1.732; |
| 7 | 1.803; |
| 8 | 1.863; |
| 9 | 1.915; |
| 10 | 1.960; |
| 11 | 2.000; |
| 12 | 2.037; |
| 13 | 2.070; |
| 14 | 2.100; |
| 15 | 2.128; |

- Chauvenet: indicates a threshold *t*, based on the normalized sample standard deviation which is scaled by a participation factor $p_N$
- Possible outlier → $x_i - \overline{x} > p_N \sigma$
- Dark gray shadow indicates $\pm\sigma$ and the light-gray the N-scaled threshold $\pm p_N \sigma$
- We than raised a yellow/red alert for any BRF experiment with more than 10%/25% of possible outliers
- Weakness of the method: *a)* average depends on the outlier values. No operational iteration performed. *b)* Possible Clustering of models not handled. *C) might be improved by setting a minimum acceptable error (1%).*

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# Feedback Phase (Chauvenet)

- Examples of wrong data driven average for the BRF in the azimuth ring
- Not optimal but rather simple and pragmatic method to identify problems
- The model-to-model comparison and robust methodology described later will allow us to identify the possible Custom and Robust references

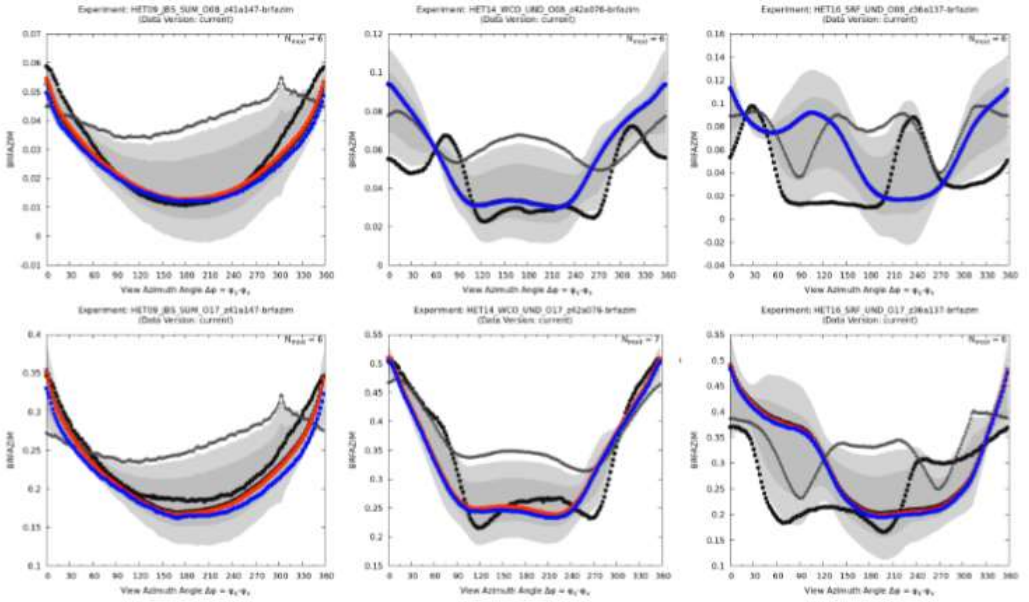
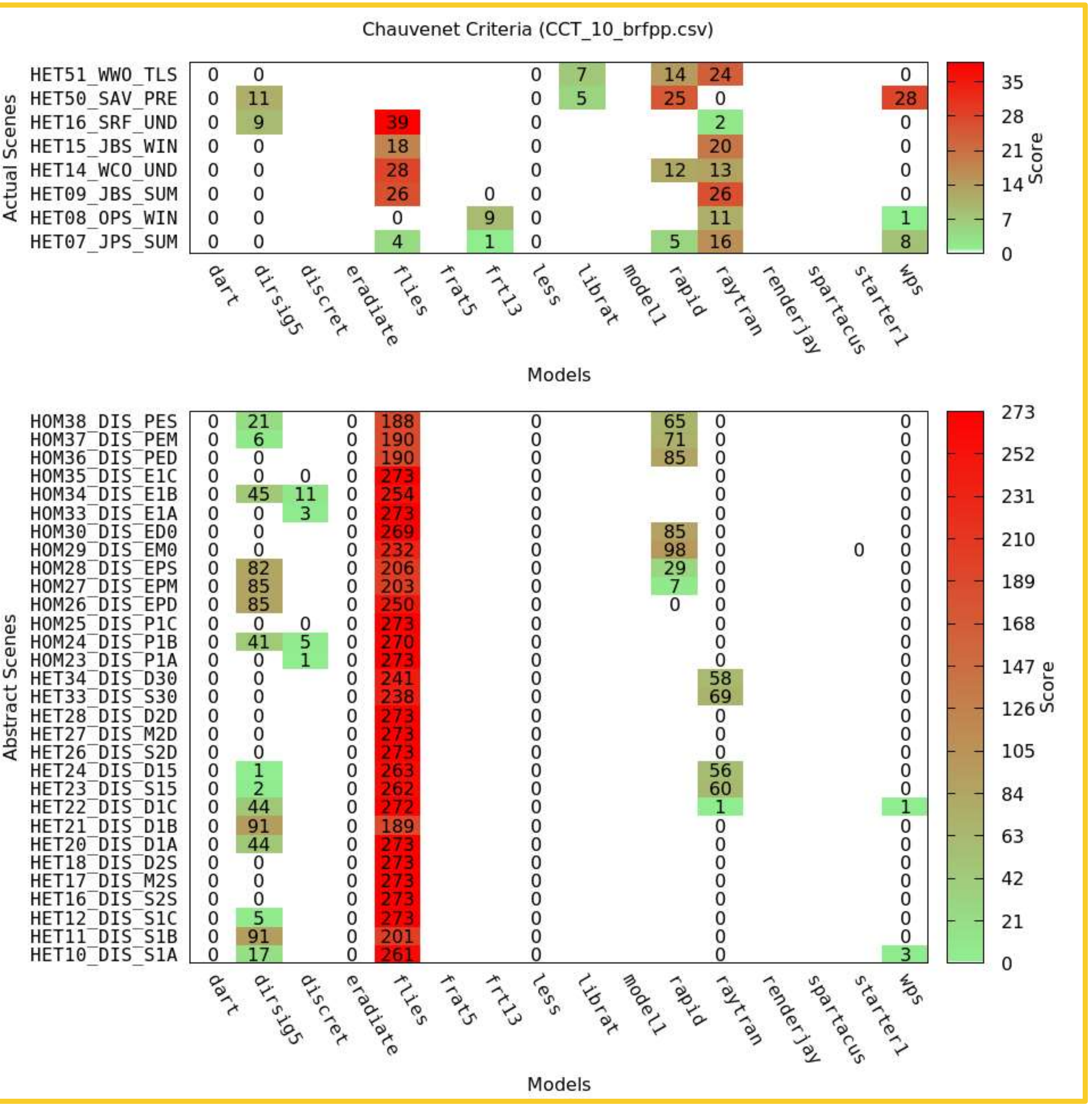
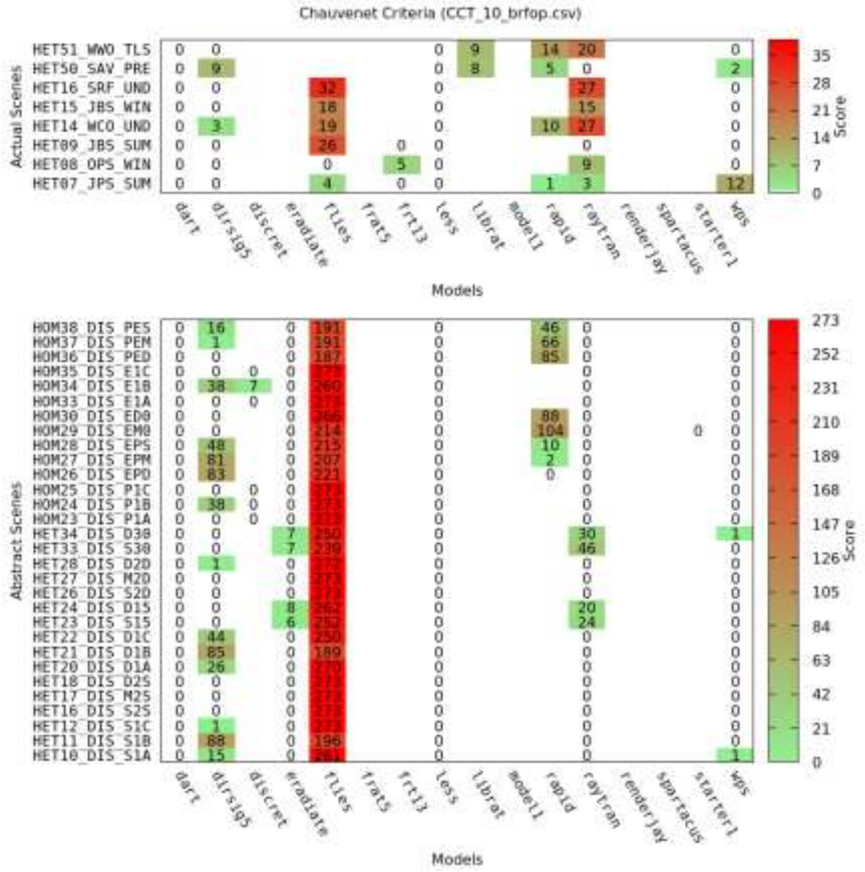


Figure 5: Examples of model simulated domain-level BRFs along an azimuth ring (*brfazim*) at $\theta_v = 37°$ for the pinestand model (HET07), and the two structured actual canopies HET14 and HET16. The upper figures show results in the visible band (O08) and the lower in the near-infrared band (O17).




# Chauvenet Summary example (brfpp, brfop) -- 20220923

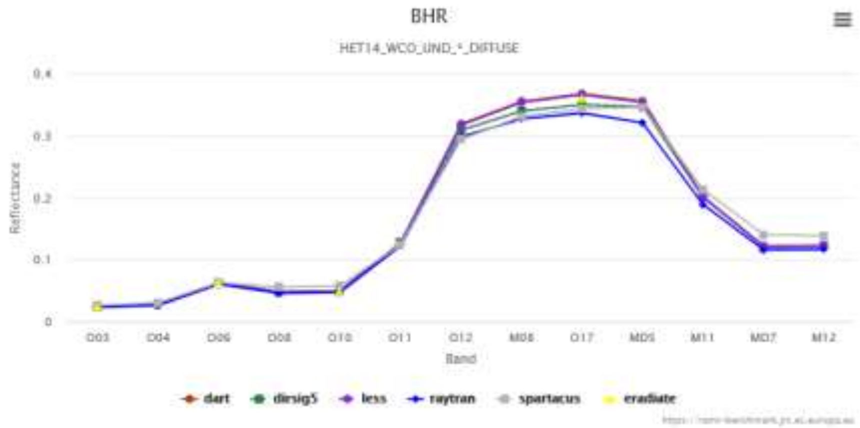


# Preliminary results

2021 | 2023

Wellington Citrus Orchard
**HET14_WCO_UND**

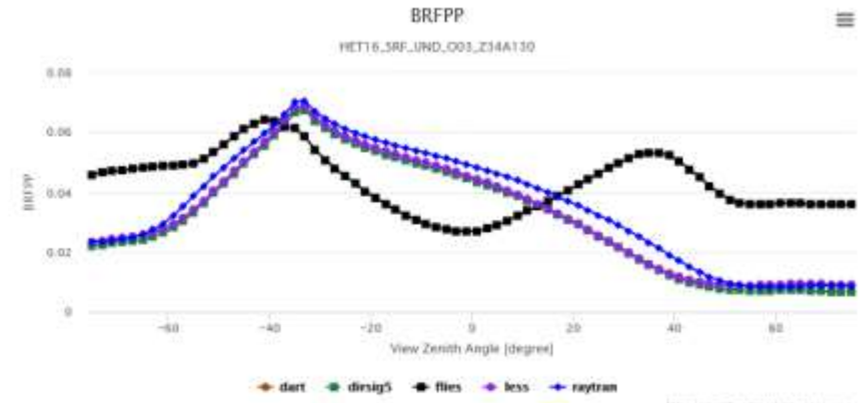
**bhr**

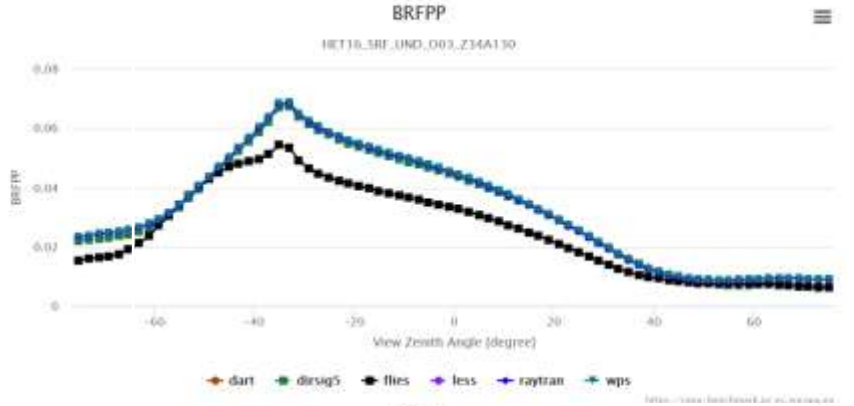





Agricultural crops Short Rotation Forest
**HET16_SRF_UND**

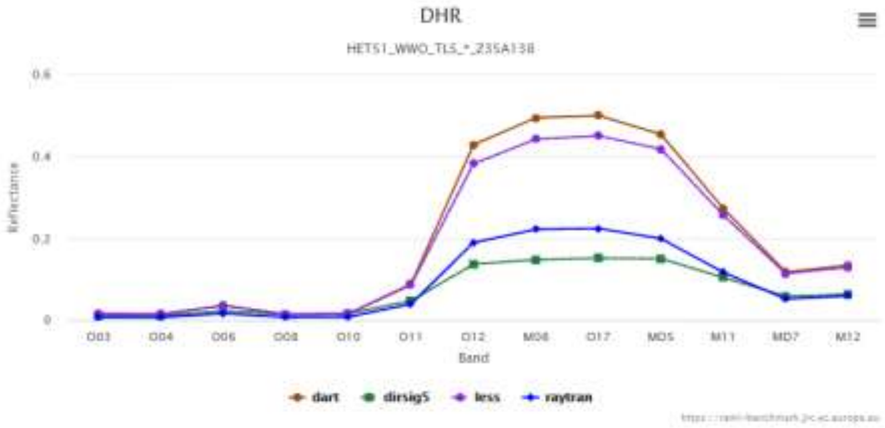
**brfpp**

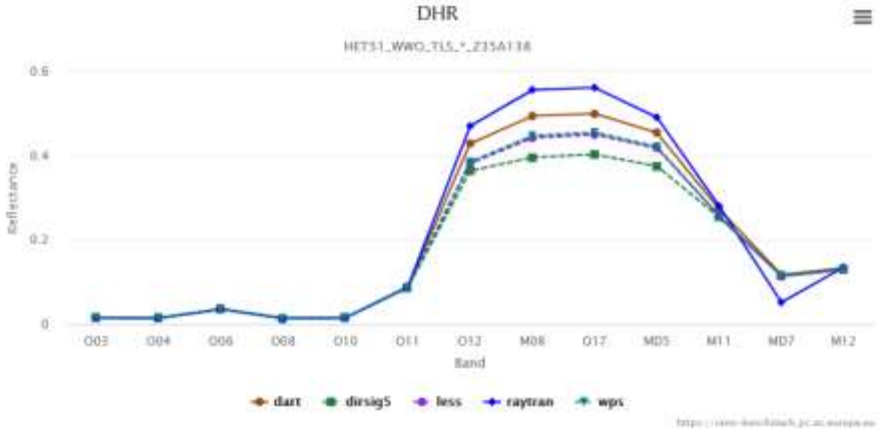



Wytham Wood
**HET51_WWO_TLS**

**dhr**



# Public results web site

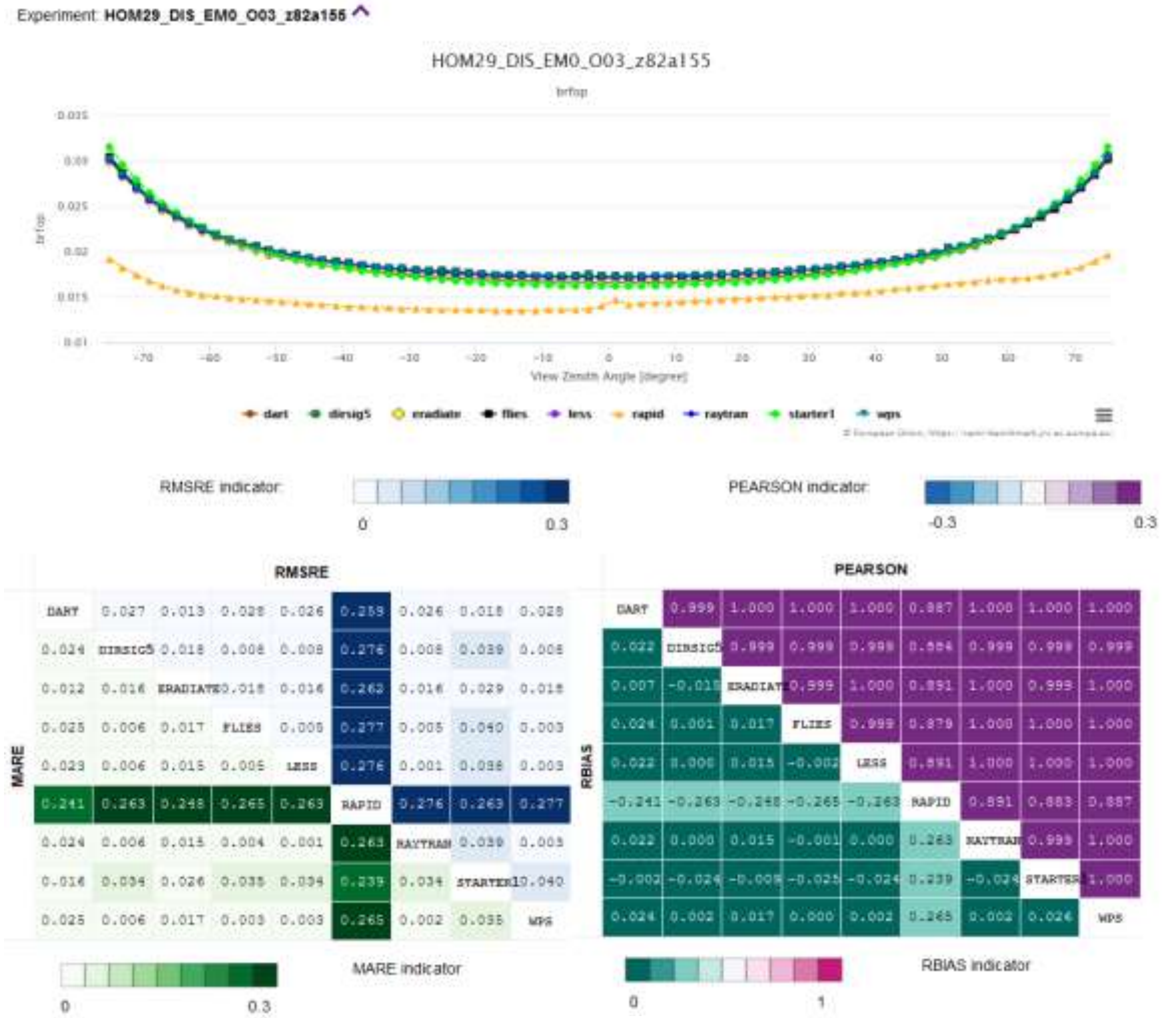
Several metrics have been calculated:

- on a **single experiment** *<Scenario>-<Meas>.mes* for BRF measurements (aggregated over $\theta_v$, *N=76*)
- aggregated on $\lambda$ for 1-value measurements (*N = 13* or 5, *bhr, dhr, fabs, ftran*).

| Name | Equation |
|---|---|
| BIAS | $BIAS(X,Y) = \frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)$ |
| Relative bias | $rBIAS(X,Y) = \frac{2}{N}\sum_{i=1}^{N}\frac{(x_i - y_i)}{(x_i + y_i)}$ |
| Root-Mean-Square Error | $\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - y_i)^2}$ |
| Root-Mean-Square Relative Error | $\sqrt{\frac{4}{N}\sum_{i=1}^{N}\frac{(x_i - y_i)^2}{(x_i + y_i)^2}}$ |
| Mean Absolute Error | $MAE = \frac{1}{N}\sum_{i=1}^{N}\lvert x_i - y_i\rvert$ |
| Mean Absolute Relative Error | $MARE = \frac{2}{N}\sum_{i=1}^{N}\frac{\lvert x_i - y_i\rvert}{x_i + y_i}$ |
| Pearson correlation coefficient | $r = \frac{\sigma_{xy}}{\sigma_x \sigma_y} = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2}\sqrt{\sum(y_i - \bar{y})^2}}$ |

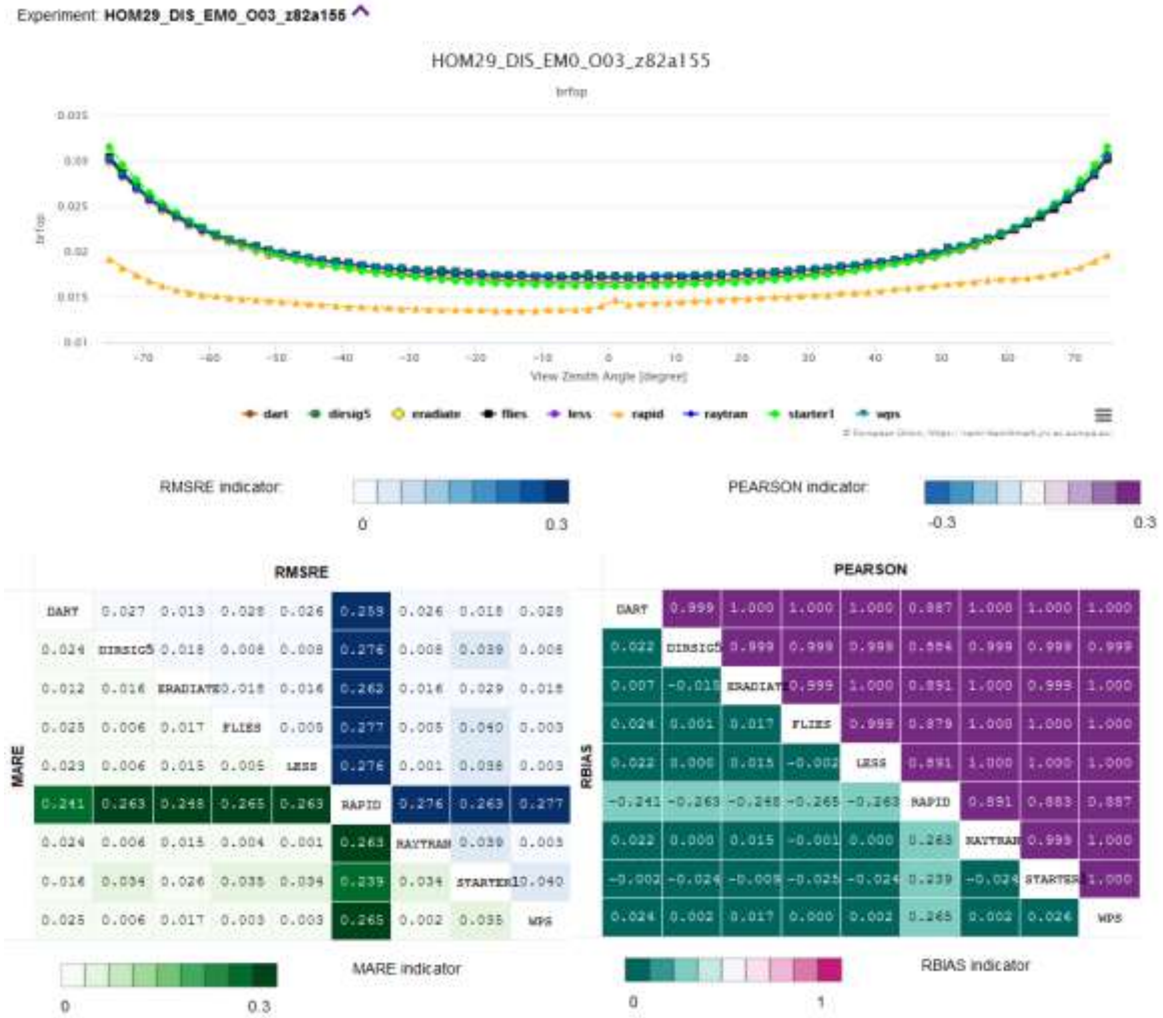
# Public results web site

- Results are presented by means of their BRF($\theta_v$) and A($\lambda$) plots and the corresponding Metrics represented by correlograms heatmaps
- MARE, RMSRE, PEARSON, RBIAS



# Public results web site

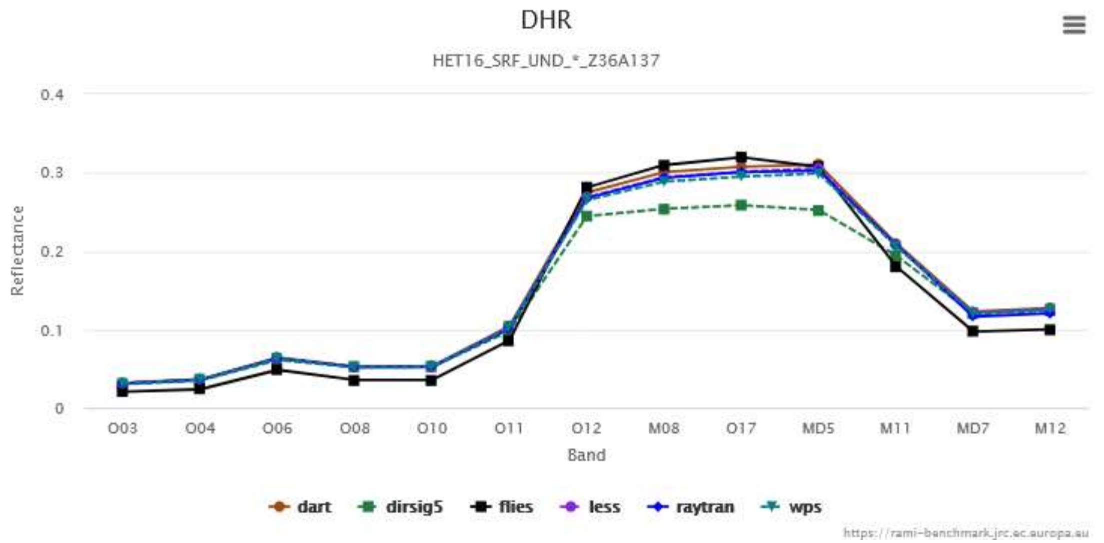
- In this particular case *eradiate* is clearly underestimating BRFOP values obtained by the other models (N=9)

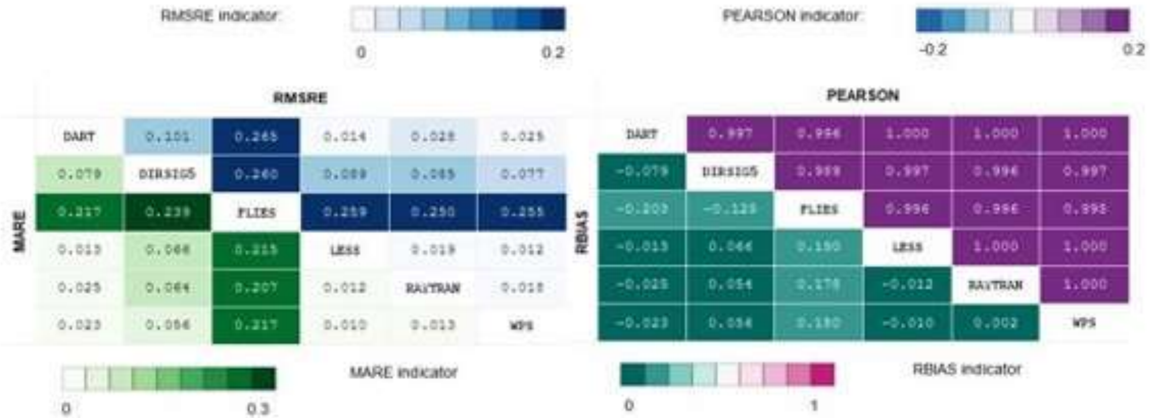



$\delta_{c\leftrightarrow m}$

# Public results web site

- In this particular case *eradiate* is clearly underestimating BRFOP values obtained by the other models (N=9)
- In the second case (aggr. λ) *flies* and *dirsig5* are underestimating the DHR value in the visible and NIR, respectively.
- MARE and RMSRE highlight the misbehavior of the models
- **Note:** These metrics, being relative, might be driven by the higher relative values in visible bands, due to the lower Reflectance.




$\delta_{c \leftrightarrow m}$

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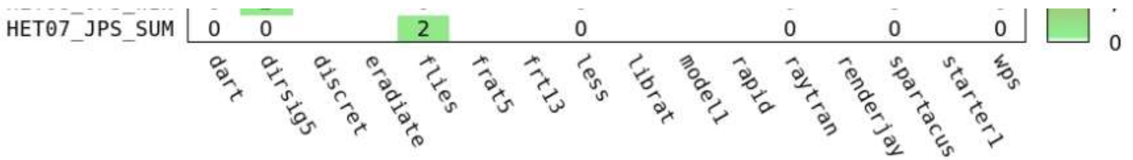


# Public results web site


- From the web interface it is possible to remove models selectively and focus on the comparison of interest
- In this specific case models *clustering* occurs and the Chauvenet methodology, in similar cases may fail to identify outliers
- Additional criteria such as participation, "credibility" (ROMC), could help driving the choice in such cases.

# Public results web site: an easy BRF case


- *A representation of the workflow to identify reference at 1-exp level*
  - *In this case clustering is not a problem*
  - *The algorithm iterates to detect Outliers until at least 2-3 models agree within a desired uncertainty*

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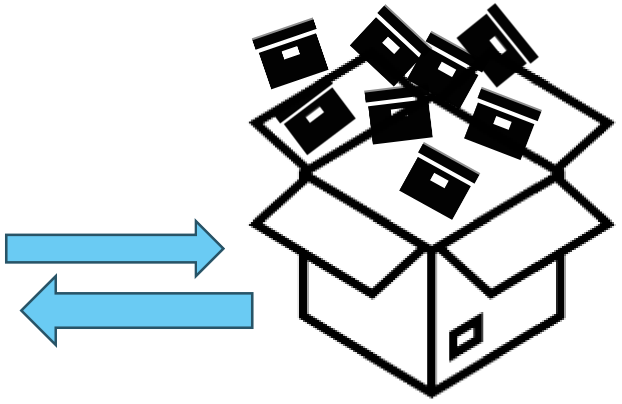
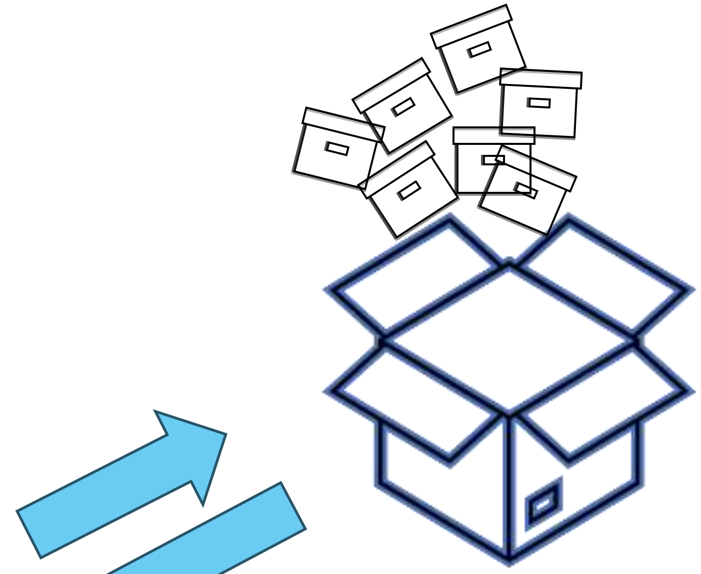
# Public results web site: aggregated heatmaps

- All metrics highlight this result and can be used to identify problems in the experiments by extracting the average, or even better the max|min values of specific metrics.
- Aggregated heatmaps

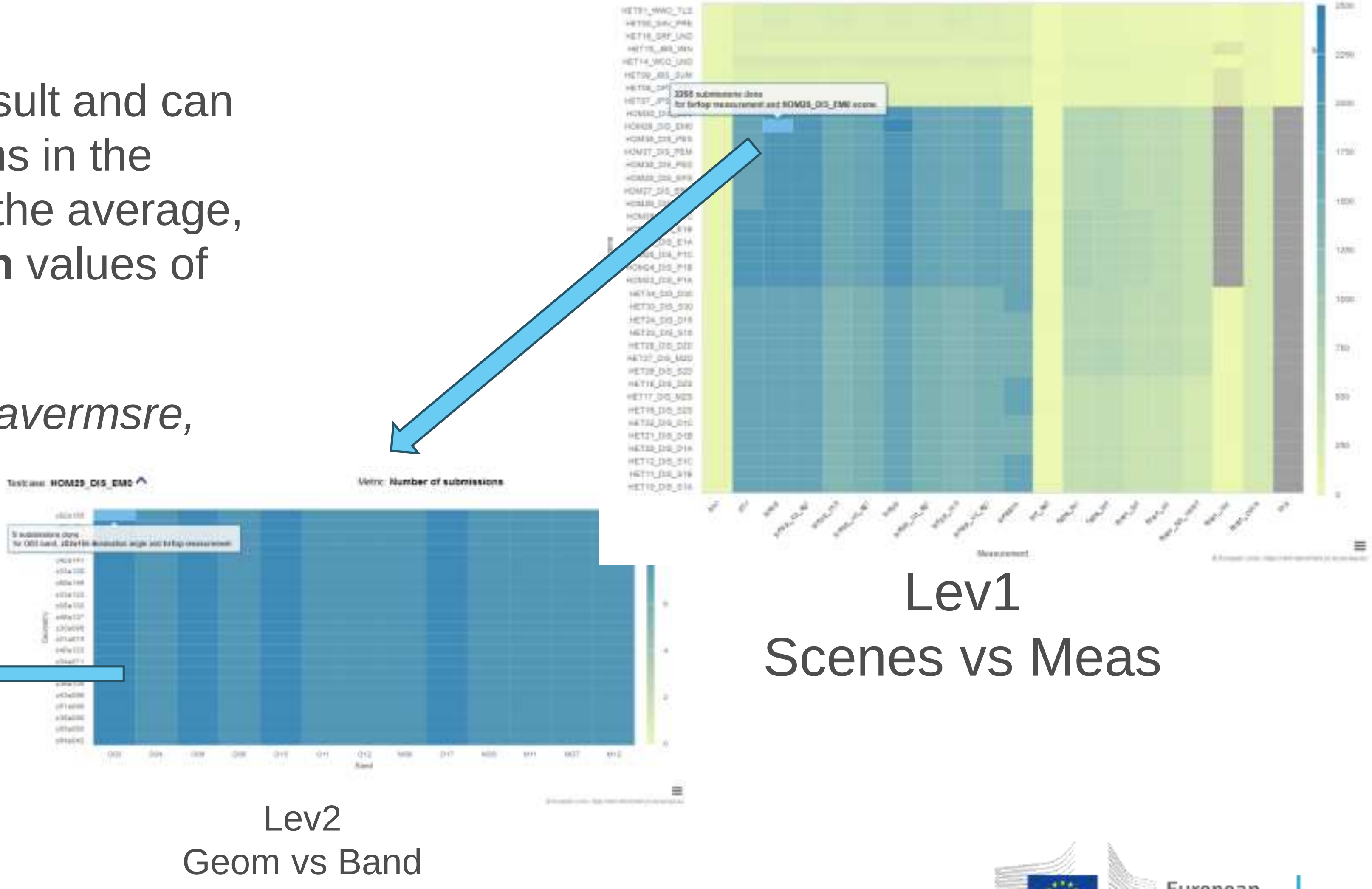
Lev2
Geom vs Band



Lev1
Scenes vs Meas

# Public results web site: aggregated heatmaps

- All metrics highlight this result and can be used to identify problems in the experiments by extracting the average, or even better the **max|min** values of specific metrics.
- Aggregated heatmaps (*N, avermsre, maxrmsre, ...*)

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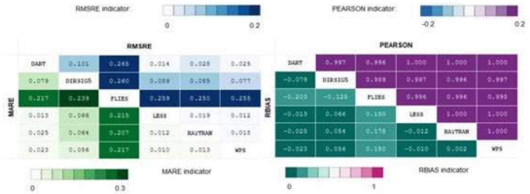
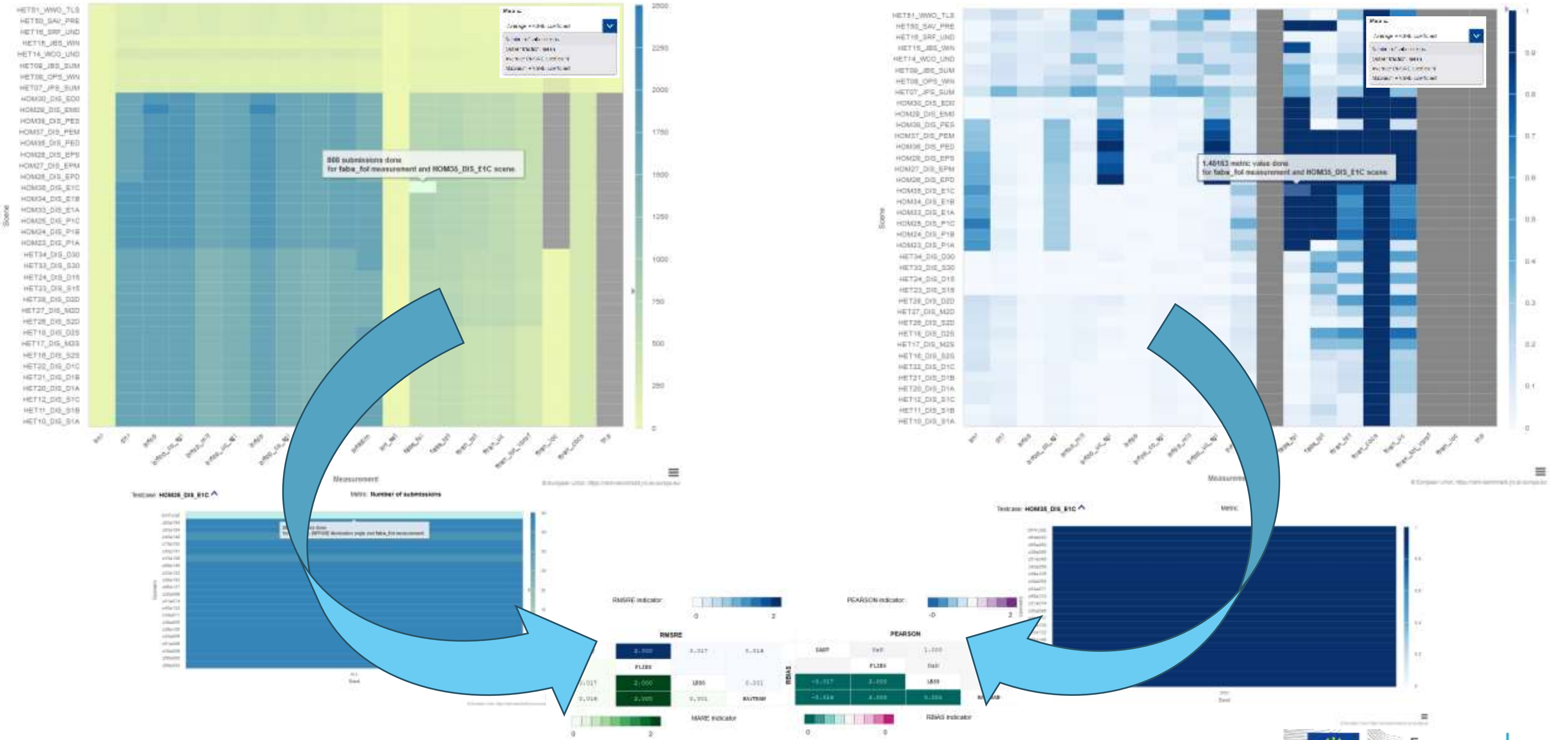


# Example: *N (left) or aveRMSRE (right)*

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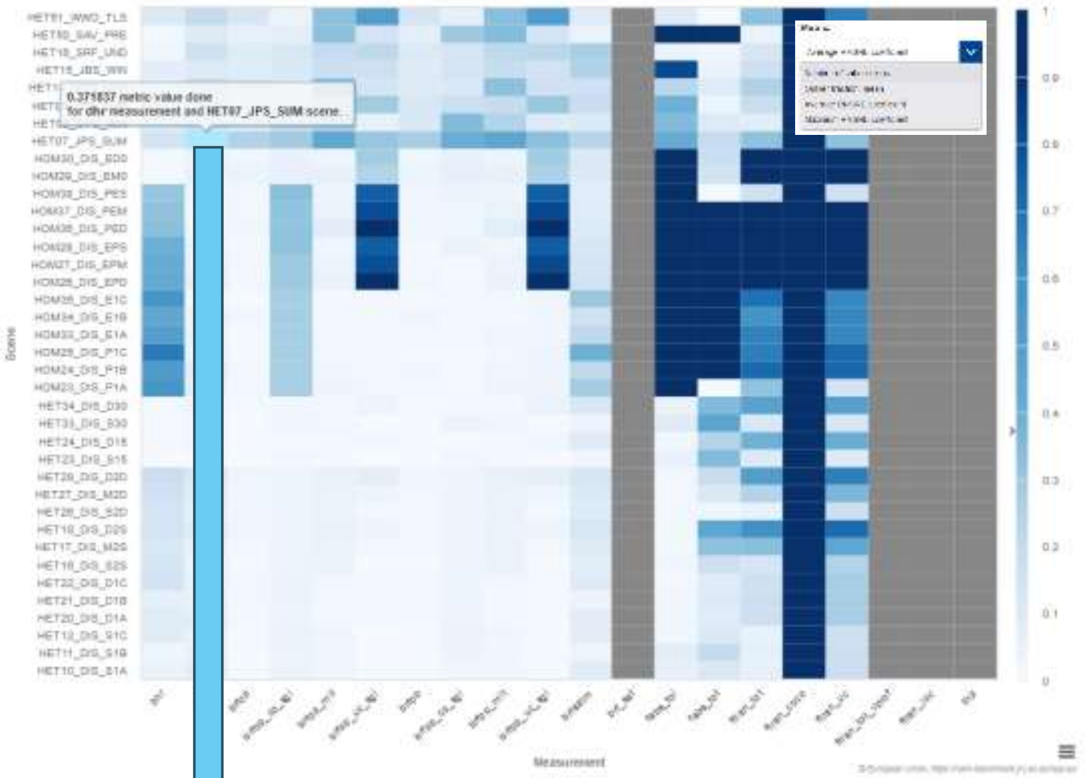
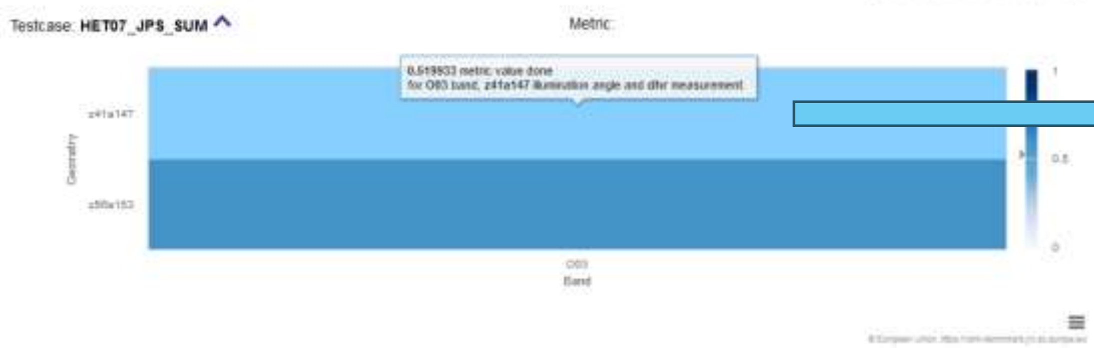
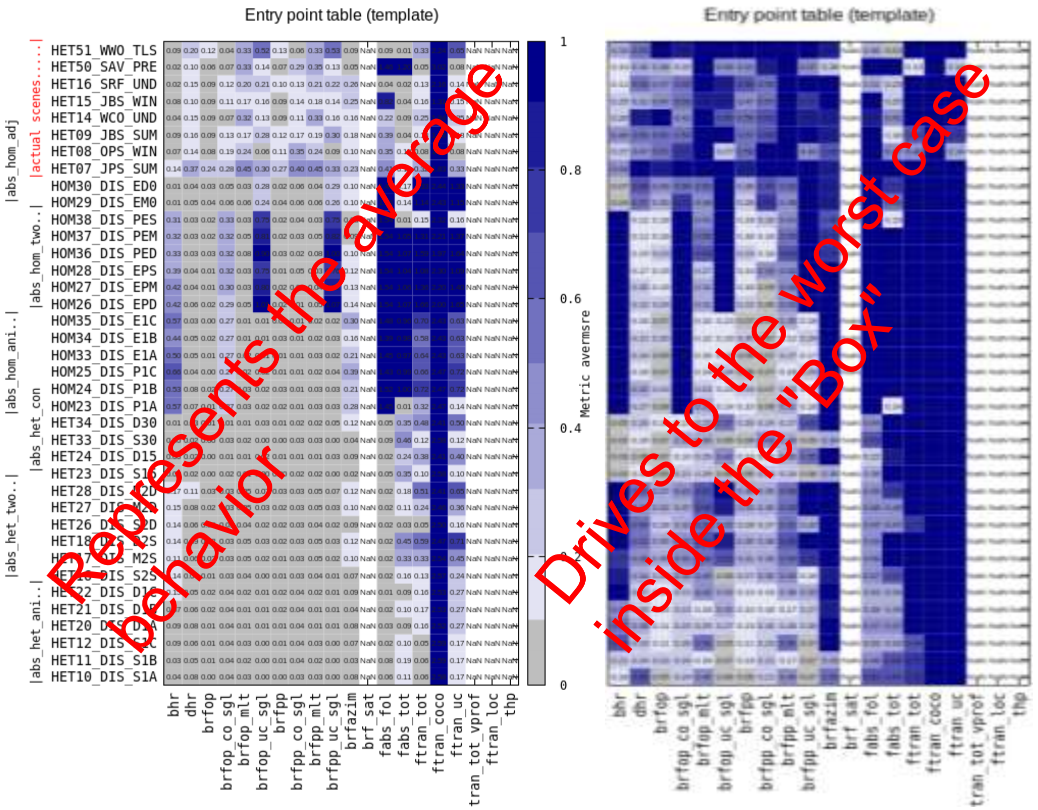
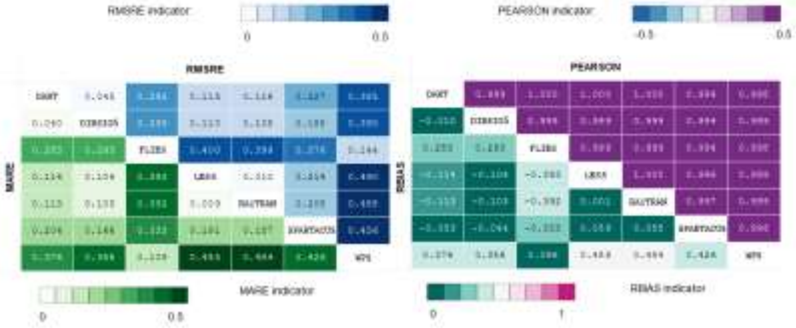
# Example: {ave,max}*rmsre*

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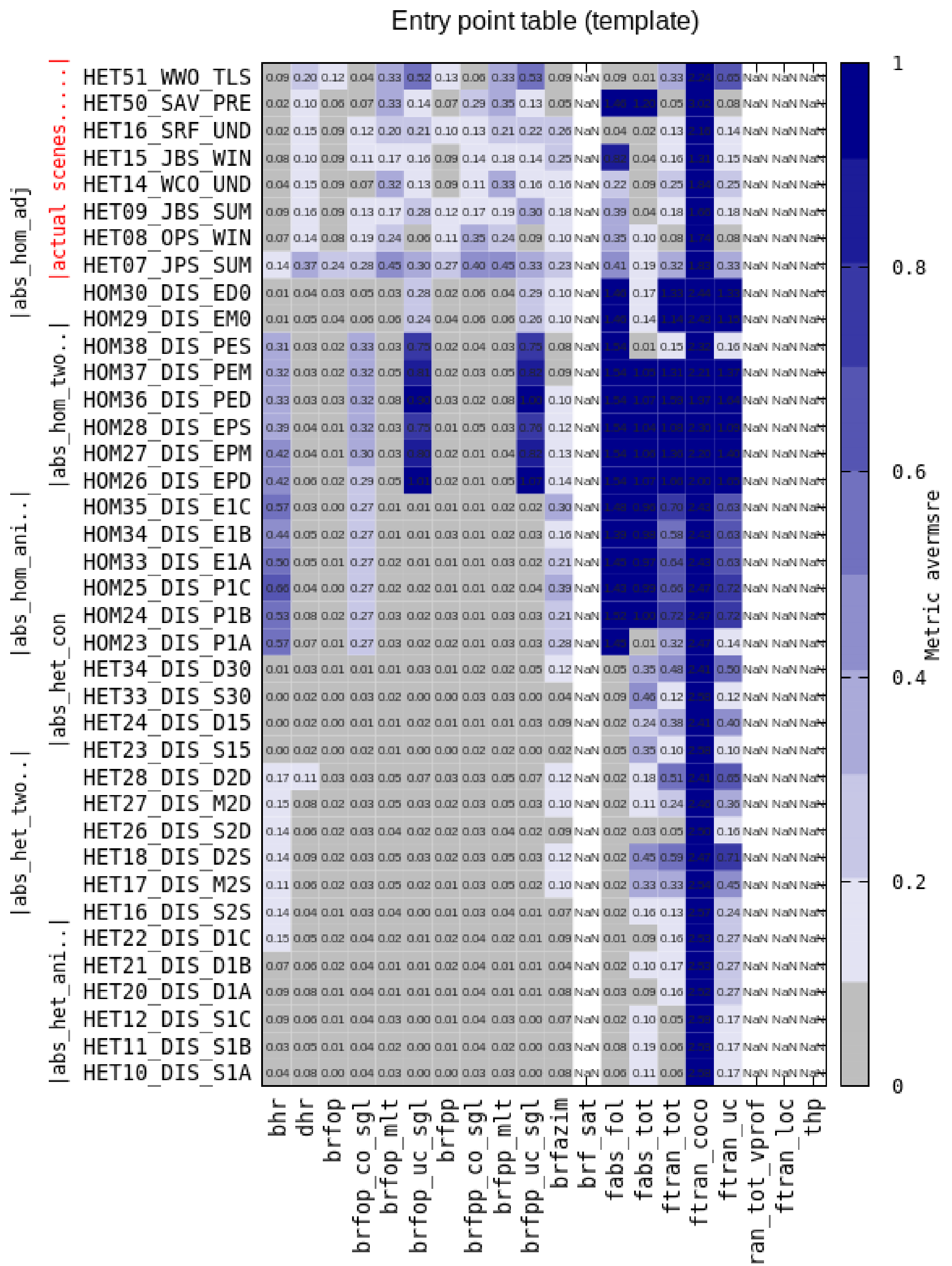


# Summary of **Lev1 RMSRE hmaps**

- Model agreement indicator of Actual is still rather lower on average than for Abstract canopies
- AveRMSRE often better than 2-5% for Abstract except for some families (home_two, hom_ani for specific brf filters)
- Rather bad values for fabs & ftran especially for homogeneous canopies
- ftran_coco (>200% systematycally) to be confirmed.
- *brf_sat* to be completed, and *thp* to be presented in terms of GAP fraction

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